Overview of CPS Assessments

Theme 1 – Scientific/technical approach for assessing status of CPS fish stocks

P. R. Crone
NOAA/SWFSC/FRD
8901 La Jolla Shores Dr.
La Jolla, CA 92037, USA
Email: Paul.Crone@noaa.gov
Tel: 858-546-7069

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Presentation outline

- Stocks – CPS assemblage inhabiting California Current Ecosystem

- Management – CPS FMP (*actively managed* vs. *monitored* stocks)

- Assessment histories and present schedules

- Assessment process (others)
  - Documentation, technical review, Council deliberations

- Assessment goals/data/models (benchmark assessments)
  - Fishery/survey/biology/ecosystem sample data
  - Model parameter assumptions, estimation, uncertainty

- Research in support of stock assessments

- Assessment strengths, challenges, and strategies for improving

CPS assemblage – NE Pacific Ocean

Vancouver Is. fishery

Washington fishery

Oregon fishery

Monterey fishery

So. Cal. fishery

Ensenada fishery

Stock distributions (– – – – –)

Fishing areas (⬭)

Pacific sardine (*Sardinops sagax*)

Pacific mackerel (*Scomber japonicus*)

Northern anchovy (*Engraulis mordax*)

Jack mackerel (*Trachurus symmetricus*)

Market squid (*Doryteuthis opalescens*)
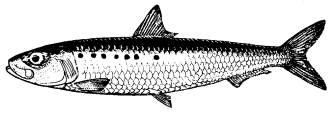
CPS biology

- Species are short lived and fast growing
- High inter-annual/-decadal variability in mortality/productivity, abundance, distribution
- General consensus ≡ dynamics largely driven by broad-scale environmental signals

CPS fisheries, assessment, management

P. sardine
- Active management
- Assessed annually
- Benchmark every 2nd yr
- Update in interim years
- High-volume fishery
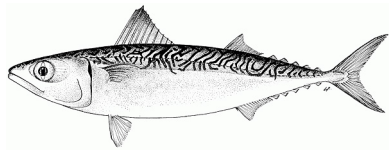
P. mackerel
- Active management
- Benchmark every 4th yr
- Harvest specs for 2-yr period
- Projection estimate in 2nd interim yr
- Low-volume fishery
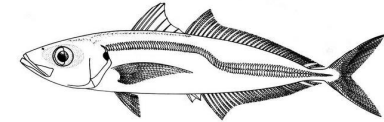- Minor species in sport fishery

N. anchovy (central sub-stock)
- Monitored management
- Low-volume fishery
- Last assessed in 1995

N. anchovy (northern sub-stock)
- Monitored management
- Low-volume fishery
- Never formally assessed

J. mackerel
- Monitored management
- Low-volume fishery
- Never formally assessed

M. squid
- Monitored management
- Active management – CA FMP
- High-volume fishery
- Not formally assessed
- Egg escapement method (per-recruit)

CPS benchmark assessments – Goals, data, models

- Assessment goal
  - **Bottom-line deliverable ≡ current estimate of total stock abundance**
  - No estimates needed for unfished/virgin stock, MSY, fishing rate
- Fishery-dependent data
  - Fishery operations and associated sample data have changed
  - Commercial: catch, sex, length/weight, age, maturity
  - Recreational: catch,CPFV logbook, RecFIN/CRFS statistics (CPUE, length)
  - Spatial coverage very limited relative to stock distributions at large
- Fishery-independent data
  - Surveys have changed
  - SWFSC acoustic-trawl method (ATM) survey: Spring (DEPM) and Summer (SaKe)
  - SWFSC CalCOFI survey (eggs/larvae): Daily Egg Production Method (DEPM)
  - Other surveys (not used): Northwest aerial, NWFSC/SWFSC forage fish, Canada DFO trawl, IMECOCAL eggs/larvae, SWFSC juvenile rockfish survey
- Models for CPS assessments
  - Models have changed (age-structured models, mid 1990s-present)
    - ✓ **P. sardine**: CANSAR→CANSAR-TAM→ASAP→SS
    - ✓ **P. mackerel**: ADEPT→ASAP→SS

CPS benchmark assessments – Data

- **P. sardine**
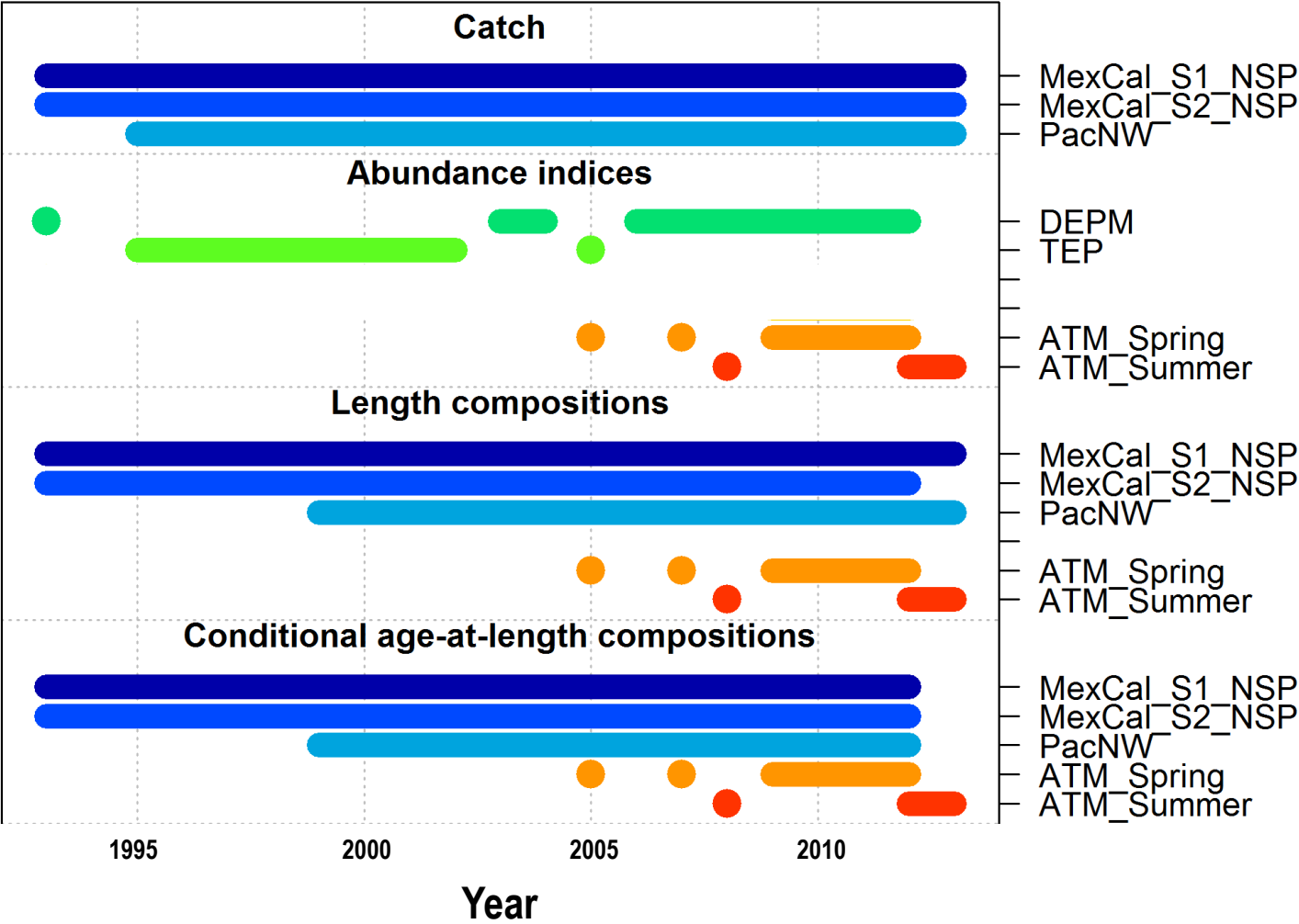 - Catch
    - ✓ Commercial (USA, MEX, CAN)
  - Indices of abundance
    - ✓ Acoustic-trawl method survey (ATM) – 2
    - ✓ CalCOFI survey –2
  - Biological compositions
    - ✓ Length
    - ✓ Conditional age-at-length (CAAL)
  - Biology parameters
    - ✓ Weight-length, length-at-age, maturity

- **P. mackerel**
  - Catch
    - ✓ Commercial (USA, MEX)
    - ✓ Recreational (USA)
  - Indices of abundance
    - ✓ CPFV logbook – recreational
    - ✓ CRFS – other recreational fishing modes
  - Biological compositions
    - ✓ Age (commercial)
    - ✓ Length (recreational)
    - ✓ Mean size-at-age
  - Biology parameters
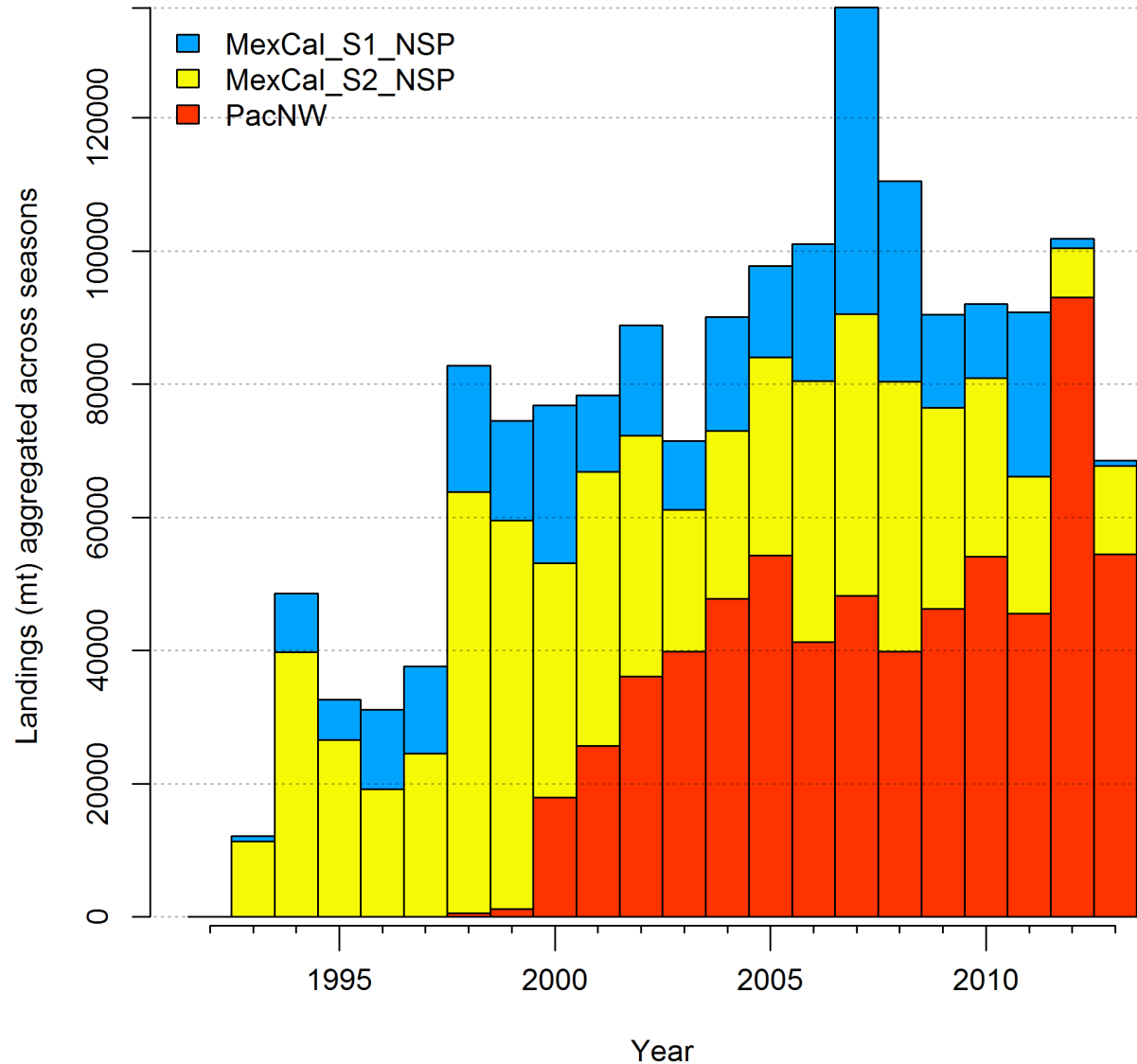   - ✓ Weight-length, length-at-age, maturity

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CPS benchmark assessments – Data

P. sardine
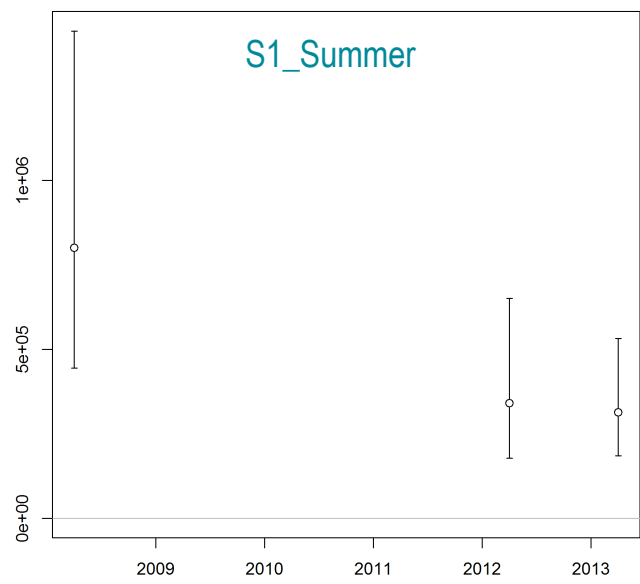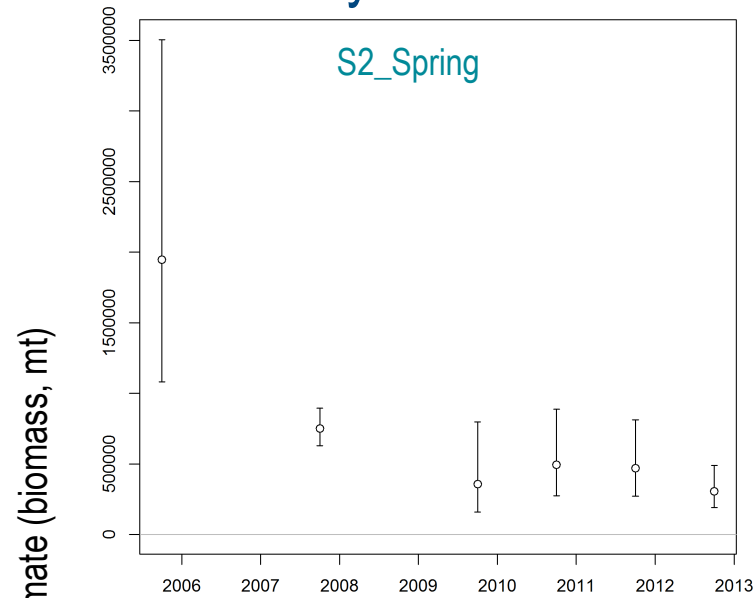
CPS benchmark assessments – Data

P. sardine – Catch

CPS benchmark assessments – Data
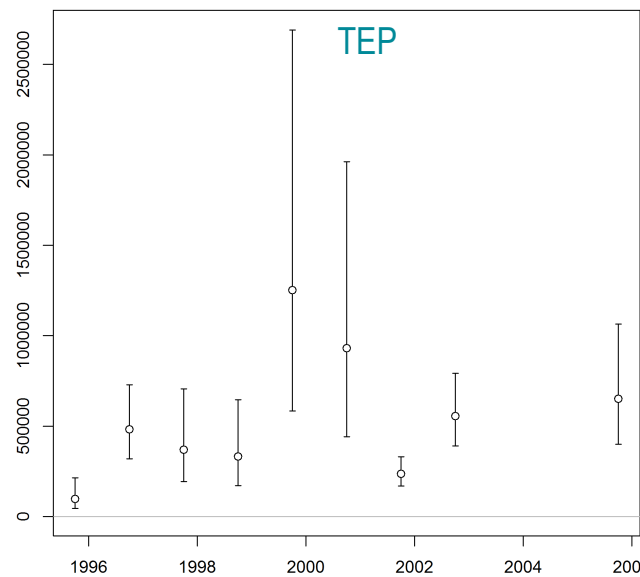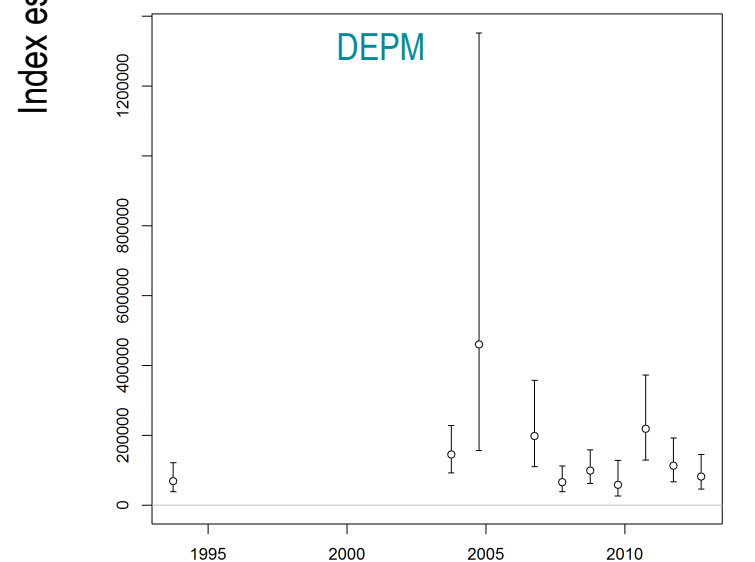
P. sardine – Survey history

YEAR	MODEL	SURVEY DATA						
		Daily Egg Production Method	Total Egg Production	CalCOFI % Positive (Eggs & Larvae)	Spawning Area	Aerial Spotter Logbook	NWSS Aerial Survey	Acoustic Trawl Method
1996	CANSAR	✓		✓	✓	✓		
1997	CANSAR	✓		✓	✓	✓		
1998	CANSAR-TAM	✓		✓	✓	✓		
1999	CANSAR-TAM	✓		✓	✓	✓		
2000	CANSAR-TAM	✓		✓	✓	✓		
2001	CANSAR-TAM	✓		✓	✓	✓		
2002	CANSAR-TAM	✓		✓	✓	✓		
2003	CANSAR-TAM	✓		✓	✓	✓		
2004	ASAP	✓				✓		
2005	ASAP	✓				✓		
2006	ASAP	✓				✓		
2007	SS	✓	✓					
2008	SS	✓	✓					
2009	SS	✓	✓				✓	
2010	SS	✓	✓				✓	
2011	SS	✓	✓				✓	✓
2012	SS	✓	✓				✓	✓
2013	SS	✓	✓				✓	✓
2014	SS	✓	✓					✓

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CPS benchmark assessments – Data

P. sardine – Survey indices
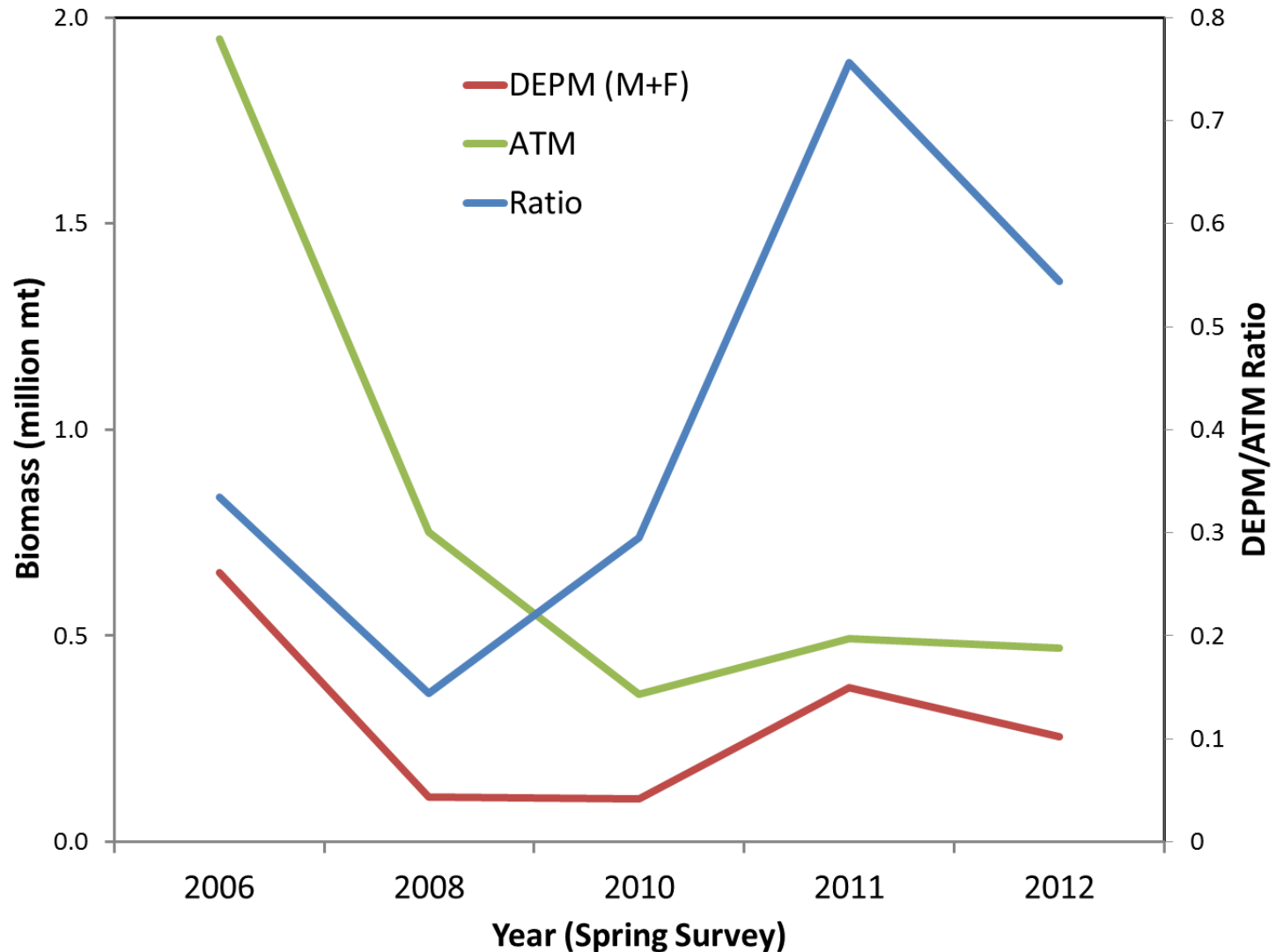

ATM

CalCOFI

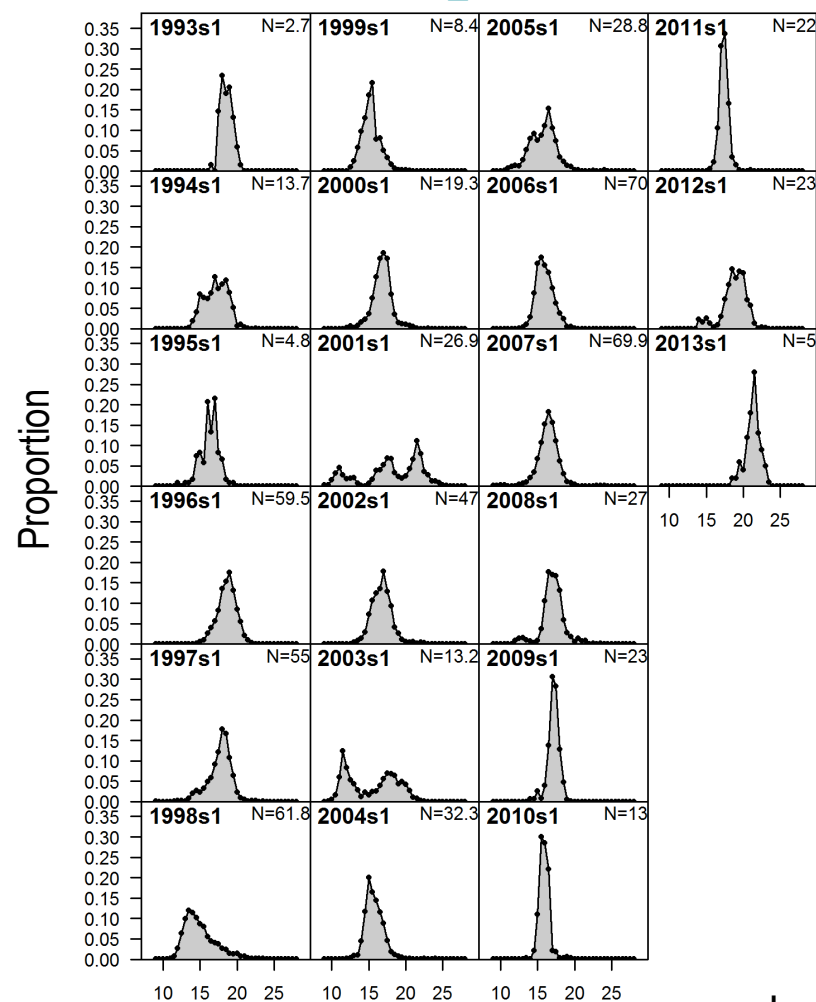Index estimate (biomass, mt)
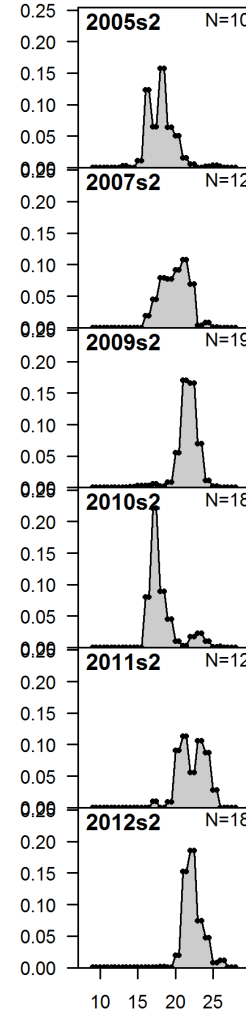
Year

CPS benchmark assessments – Data

P. sardine – Survey indices

CPS benchmark assessments – Data
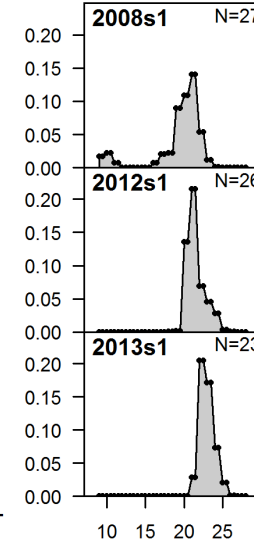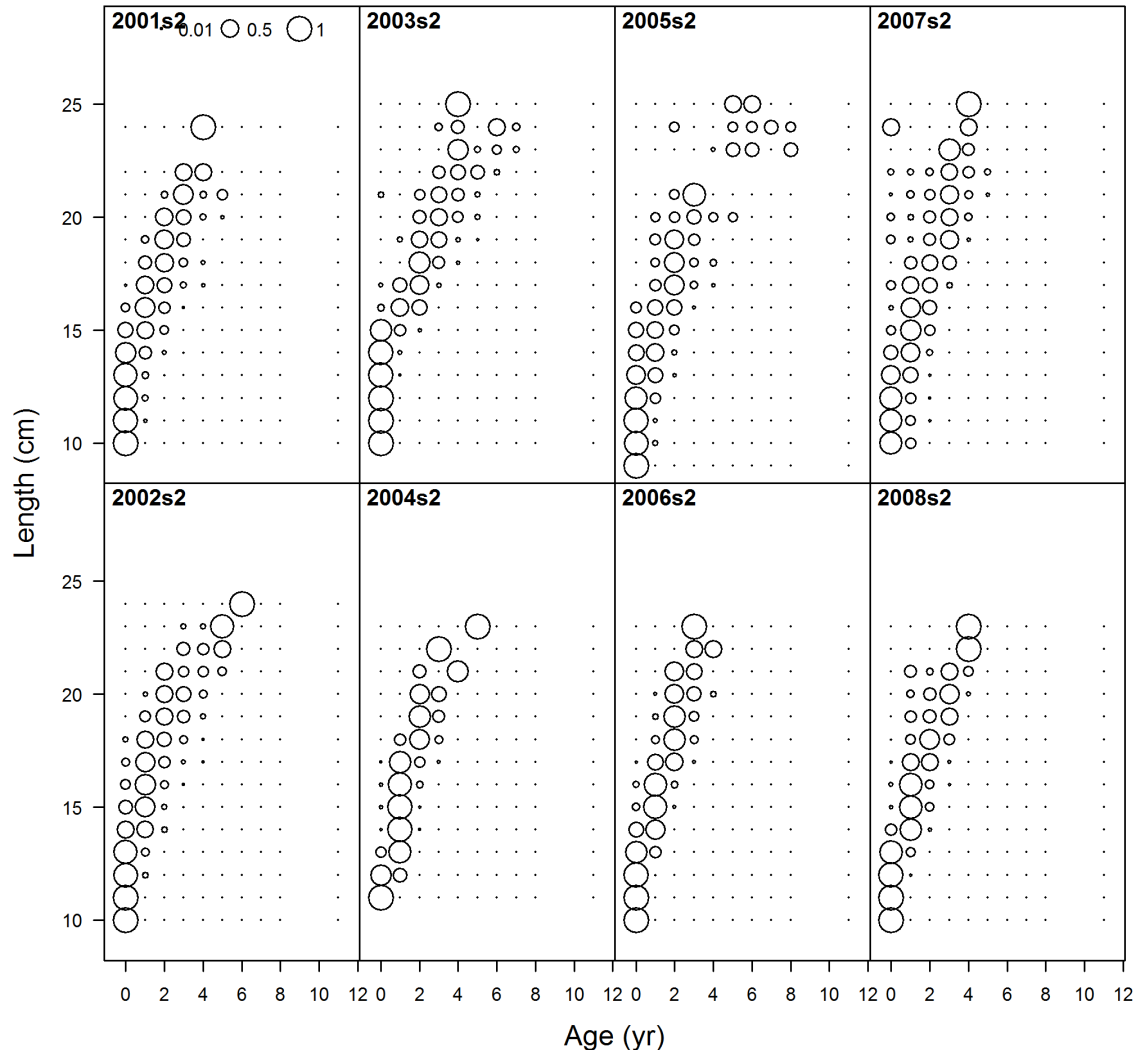
P. sardine – Length compositions

CPS benchmark assessments – Data

P. sardine – Conditional age-at-length (CAAL) compositions
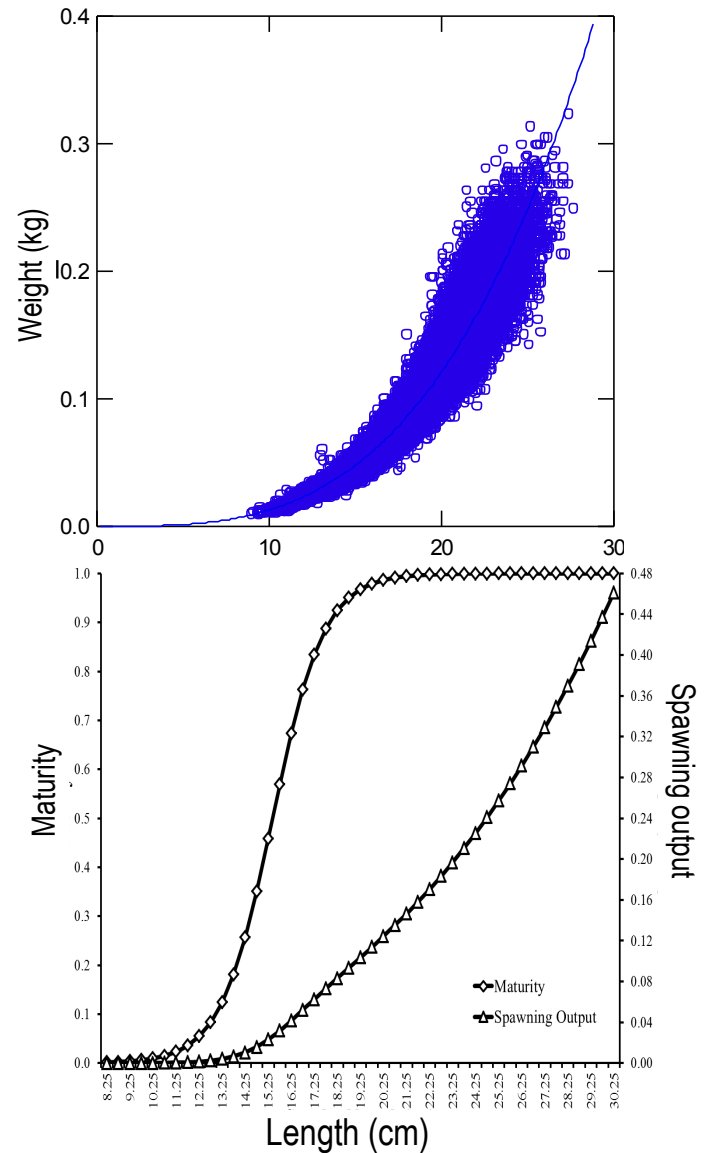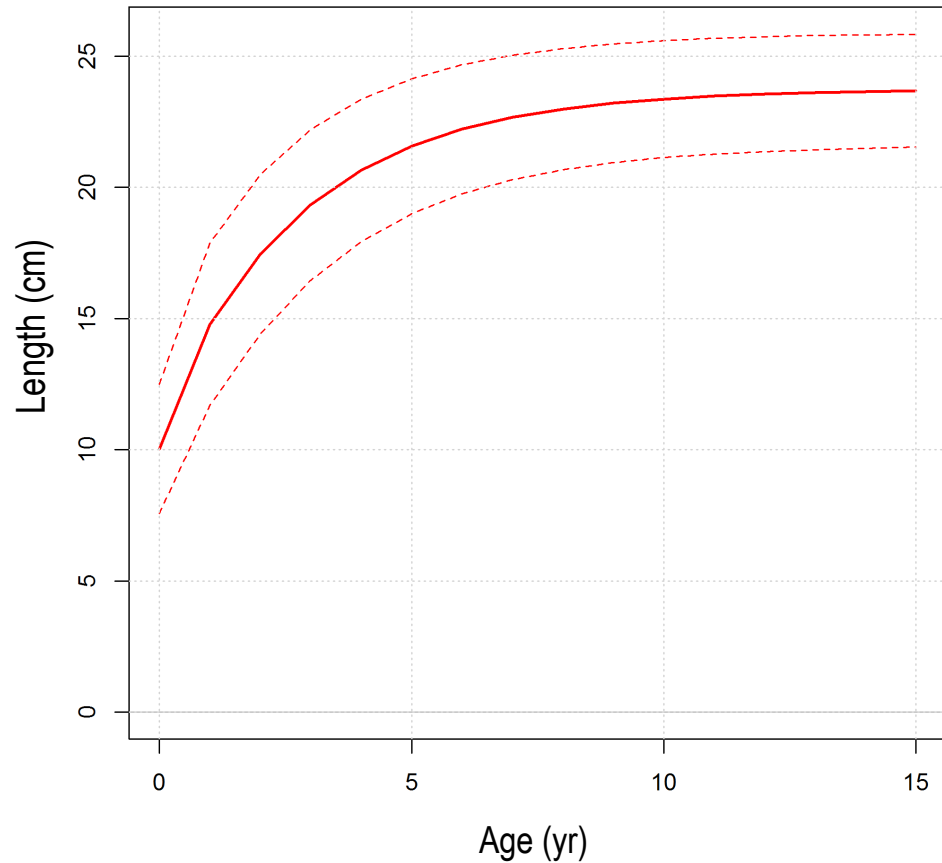

MexCal_S2

CPS benchmark assessments – Data

P. sardine – Biology

CPS benchmark assessments – Data

- Summary
  - Catch
    - ✓ High quality – USA/CAN
    - ✓ Some uncertainty/timeliness issues – MEX
    - ✓ Catch based on environmentally driven sub-stock distributions highlights additional uncertainty
  - Indices of abundance
    - ✓ Good quality
    - ✓ ATM (P. sardine) – most representative, informative, defendable (highest priority in future)
    - ✓ ATM (other CPS) – representativeness uncertain, but best available
    - ✓ DEPM/TEP (P. sardine) – representativeness uncertain, best index of early life stage strength
    - ✓ Recreational (P. mackerel) – poor quality, placeholder index presently
    - ✓ Ideally, need for coastwide (B.C. to Baja) survey conducted annually/bi-annually
  - Biological compositions
    - ✓ Pretty good quality
    - ✓ Bias in age estimation needs ongoing scrutiny – International WG (small pelagic age reading committee, SPARC)
    - ✓ Conflicts between detailed conditional age-at-length compositions and growth/selectivity
    - ✓ Compositions not available on a systematic basis – MEX
  - Biology parameters
    - ✓ High quality
    - ✓ Laboratory research ongoing, benefits model development to meet assessment goal

CPS benchmark assessments – Models

Current assessment models

- **P. sardine**
  - Stock Synthesis model
  - Time period: 1993-present
  - Time step: seasonal (semester)
  - **Stock structure**: single (northern substock)
  - **Selectivity**: length-based, time-varying
  - Catchability (q): fixed (ATM), estimated (DEPM/TEP)
  - **Spawner-recruit**: Ricker (h and σ_R fixed)
  - Biology
    - ✓ Combined sexes
    - ✓ M – fixed
    - ✓ **Growth** – estimated
    - ✓ Maturity – laboratory
  - Data weighting: compositions (CAAL)
 - No. estimated parameters: 63
  - Major changes to assessment: 2014

- **P. mackerel**
  - Stock Synthesis model
  - Time period: 1983-11
  - Time step: annual
  - Stock structure: single
  - Selectivity: age-based, constant
  - Catchability (q): estimated
  - Spawner-recruit: B-H (h estimated and σ_R fixed)
  - Biology
    - ✓ Combined sexes
    - ✓ M – fixed
    - ✓ Growth – estimated
    - ✓ Maturity – laboratory
  - Data weighting: none
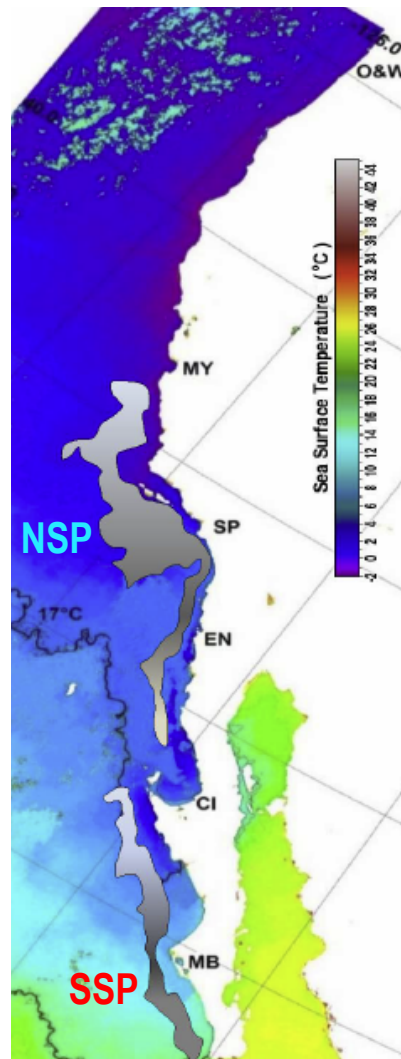 - No. estimated parameters: 57
  - Major changes to assessment: 2015

Stock structure – P. sardine

Seasonal distribution of northern and southern substocks (Garcia-Morales et al. 2012)
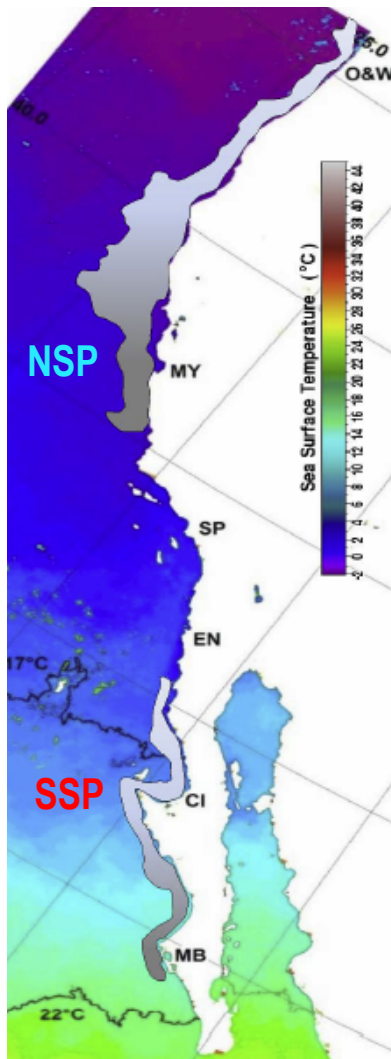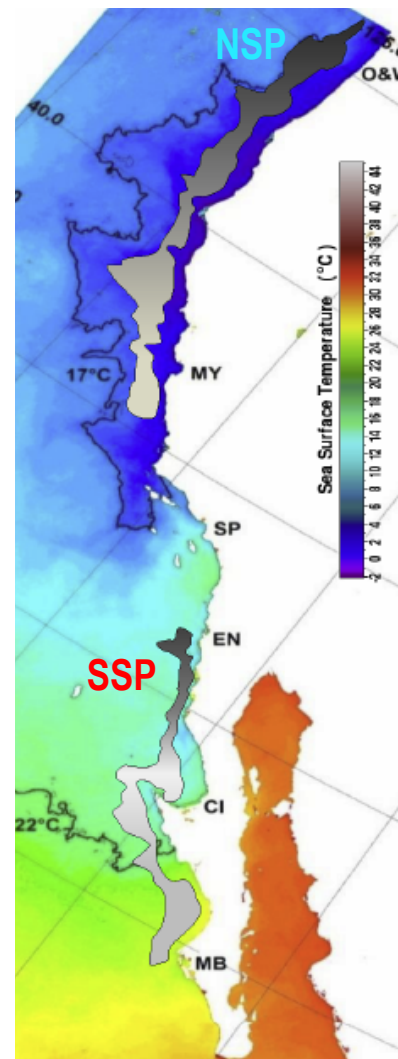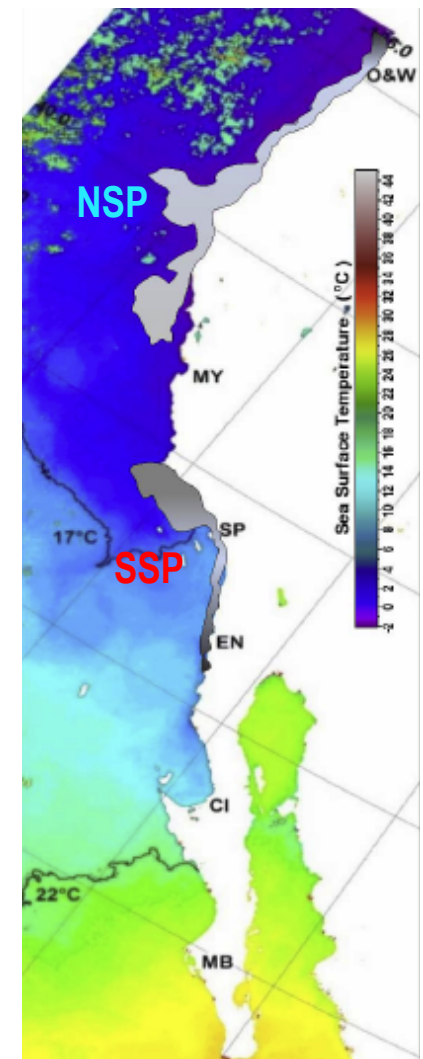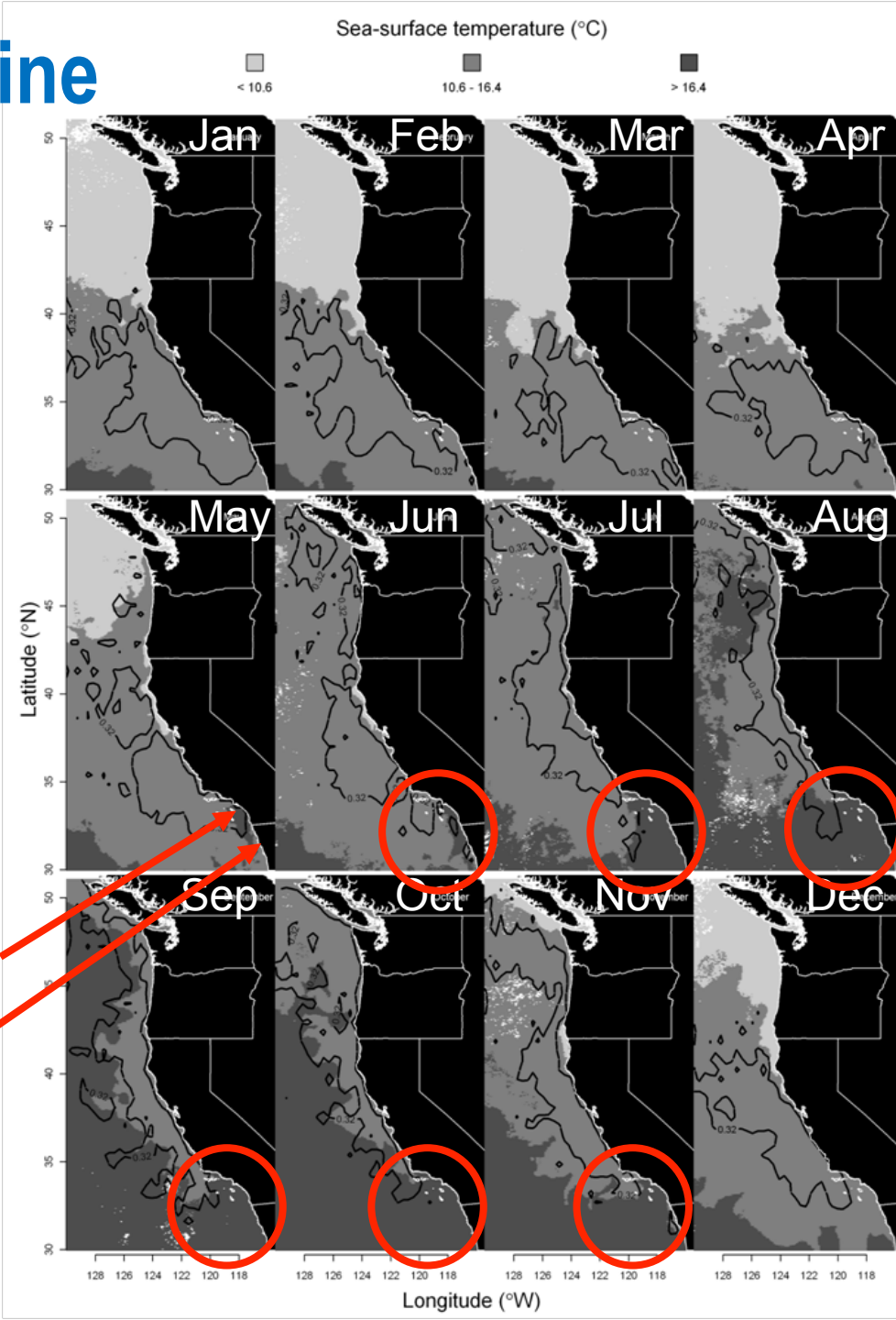
Stock structure – P. sardine

- Sub-stock differentiation
  - Zwolinski et al. (2011); Demer/Zwolinski (2014)
  - Catch based on optimal/good habitat vs. port
    - ✓ Habitat ≡ SST, chorolphyll-a, sea-surface height
  - Seasonal mixing of northern and southern sub-stocks
  - Year-round landings from Monterey northward solely from northern stock
    - ✓ Northern stock habitat present off Ensenda/San Pedro from Dec-Mar
    - ✓ Southern stock habitat present off Ensenda/San Pedro from May-Nov
    - ✓ Transitions from northern-southern stock habitats during April and vice-versa during Nov-Dec
  - Potentially, in summer months, 2/3 Ensenda catch and 1/3 San Pedro catch from southern stock (2006-11)
  - Bottom-line is reduced *F* on northern stock (USA managed) and increased *F* on southern stock (MEX managed)
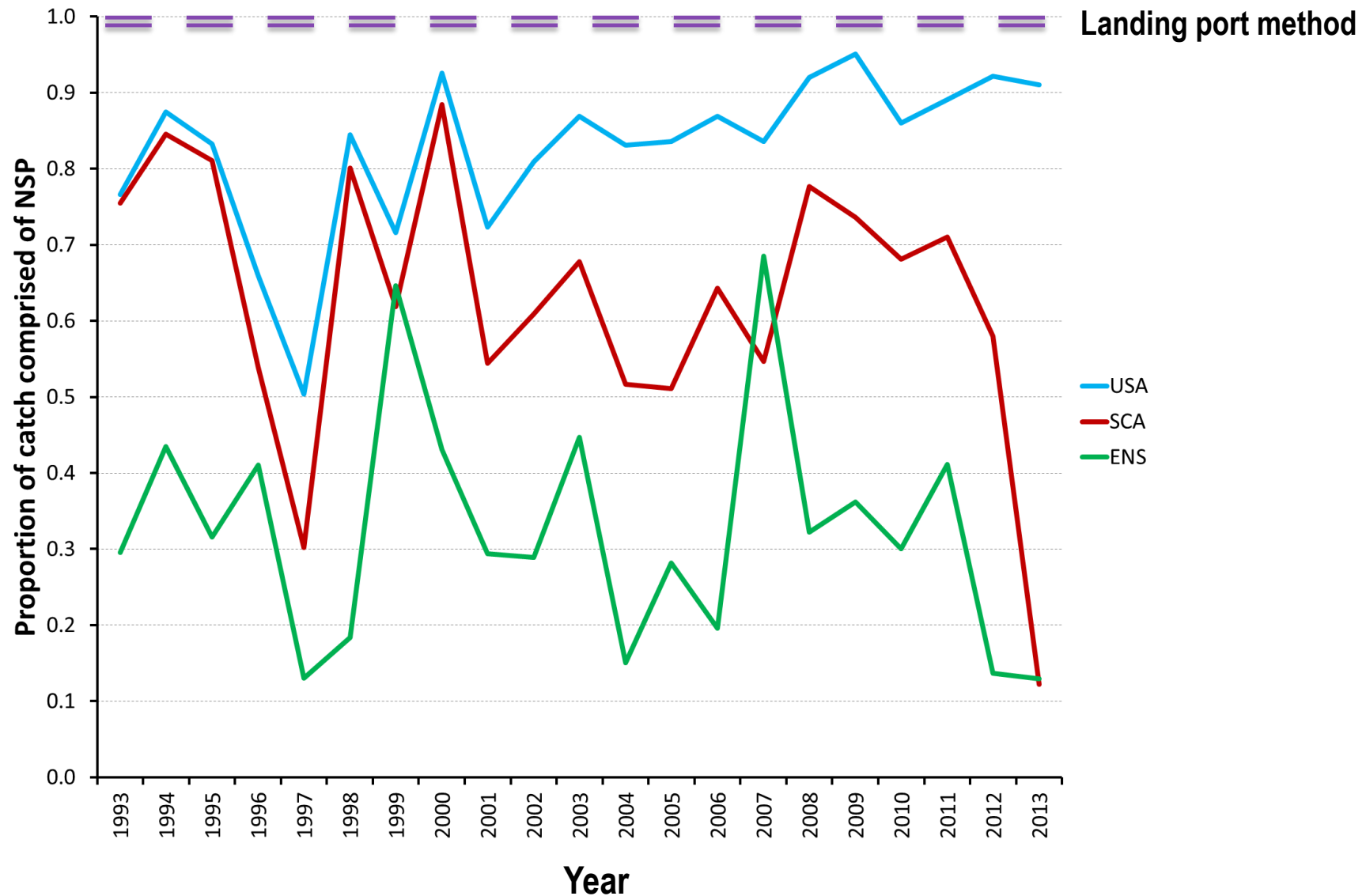
Stock structure – P. sardine

Proportion of catch attributed to northern sub-stock using good/optimal habitat method

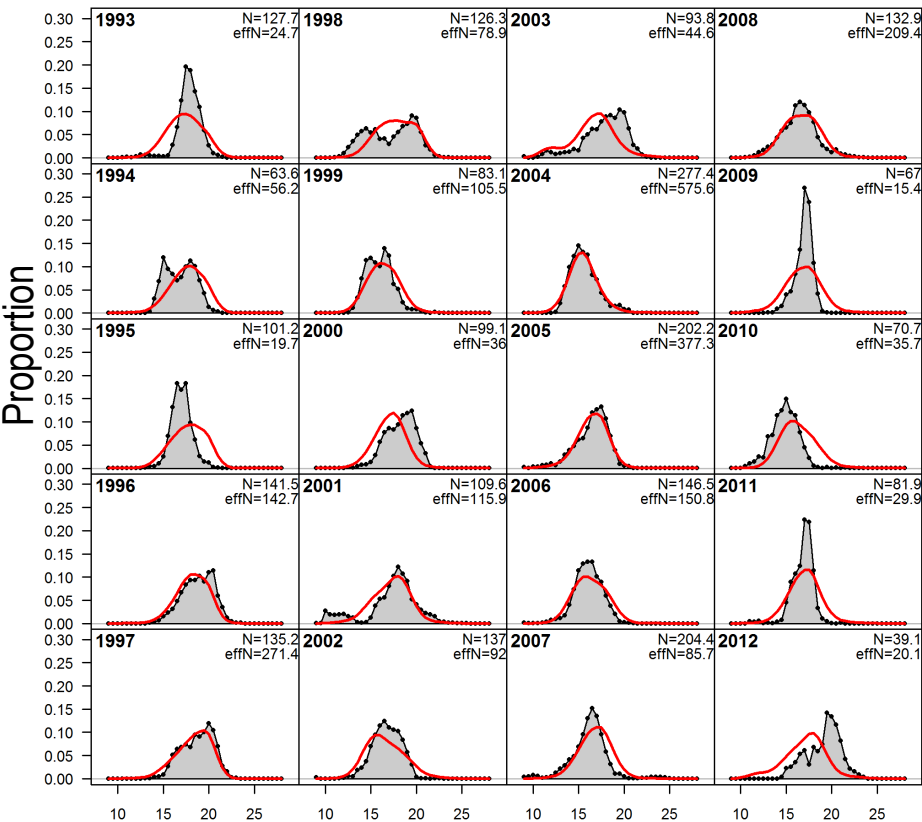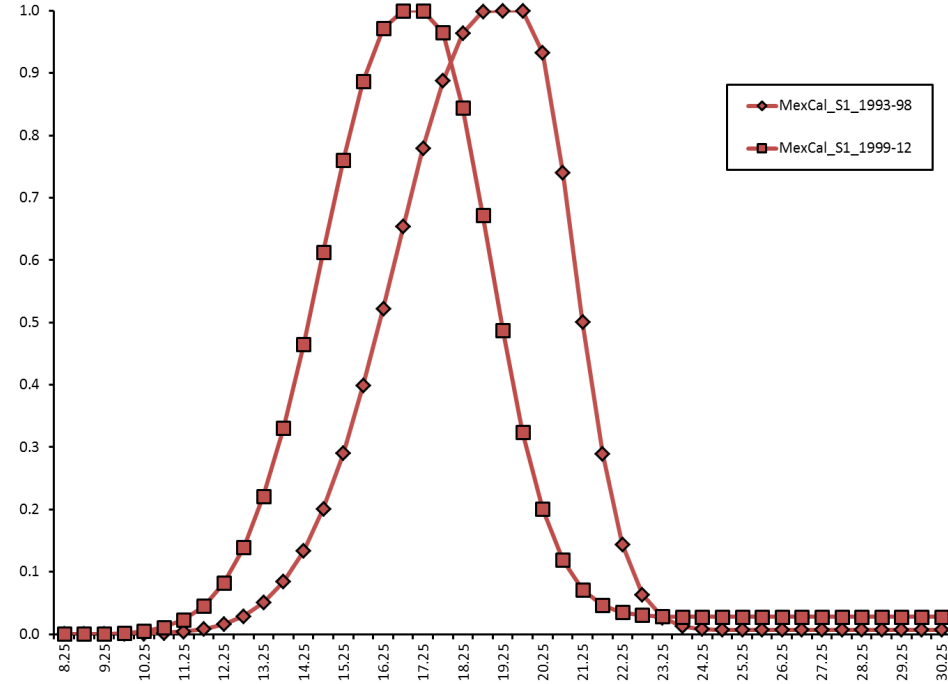# Selectivity – P. sardine

Length composition ➡ Selectivity

Length (cm)

Selectivity – P. sardine

- Consider age-based
  - Production ageing in place
  - Most straightforward model
  - More robust results?
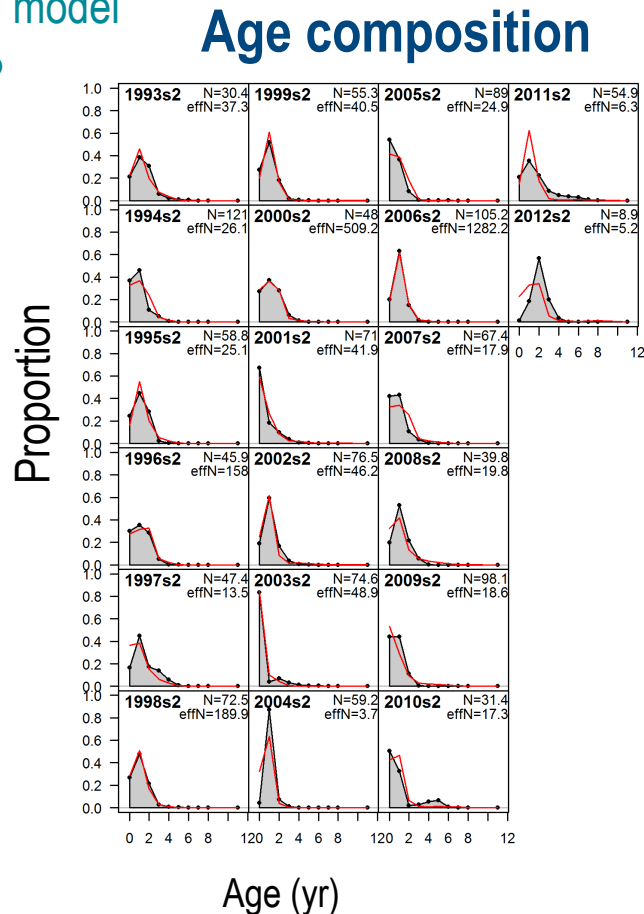
Age composition → **Selectivity**
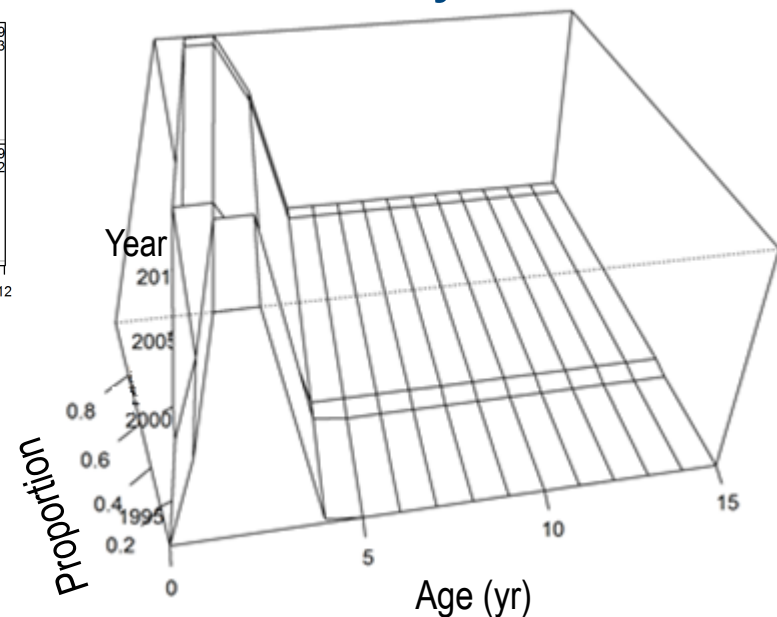
Spawner-recruit (S-R) – P. sardine

- Beverton-Holt relationship

- Steepness fixed (0.9)
  - Based on meta-analysis
  - More sensitivity analysis needed

- Environmental covariates
  - Better inform recruitment variability and S/R estimation
  - Large-scale environmental time series
  - **PDO**, MEI, NPGO, chlorophyll-a, sea-surface height, …?
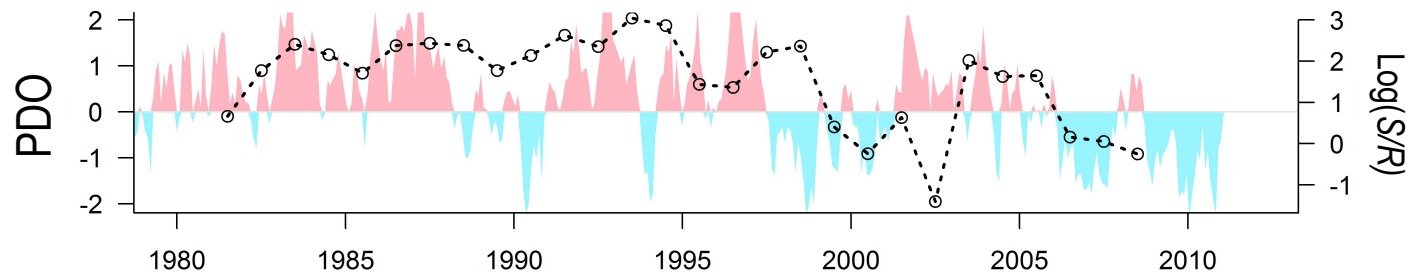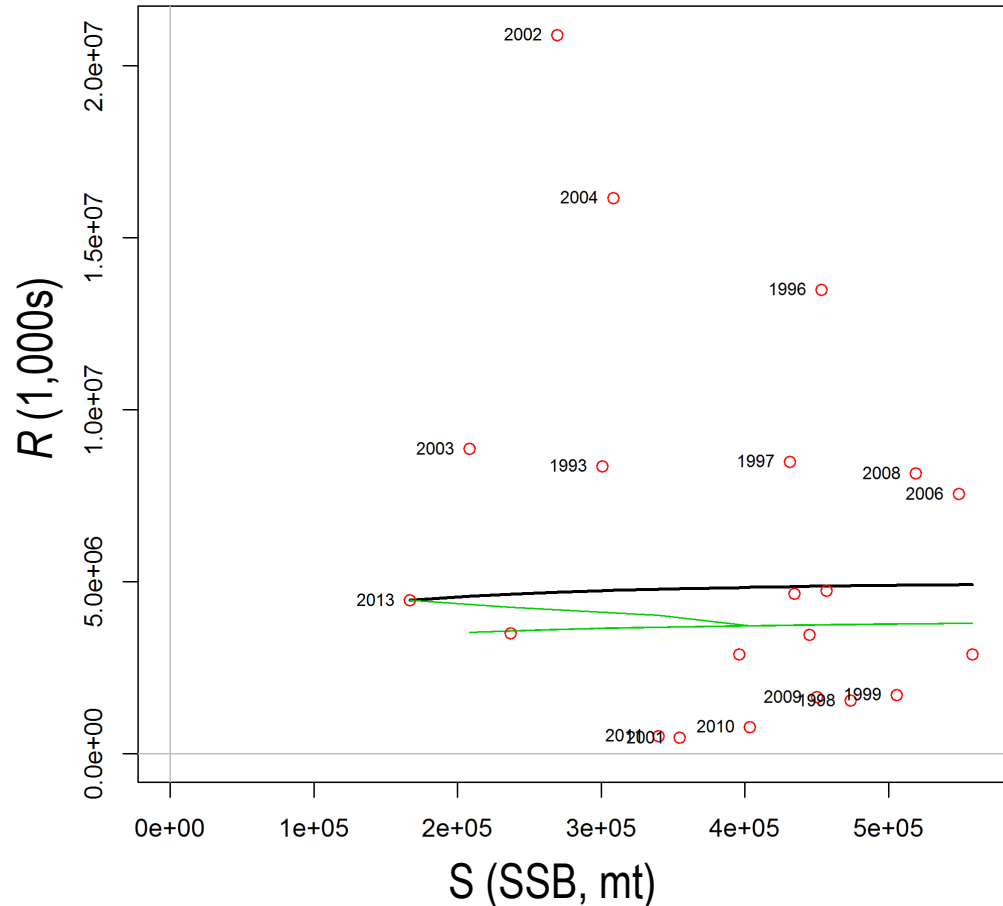
Growth – P. sardine

Conditional age-at-length ➡ Growth
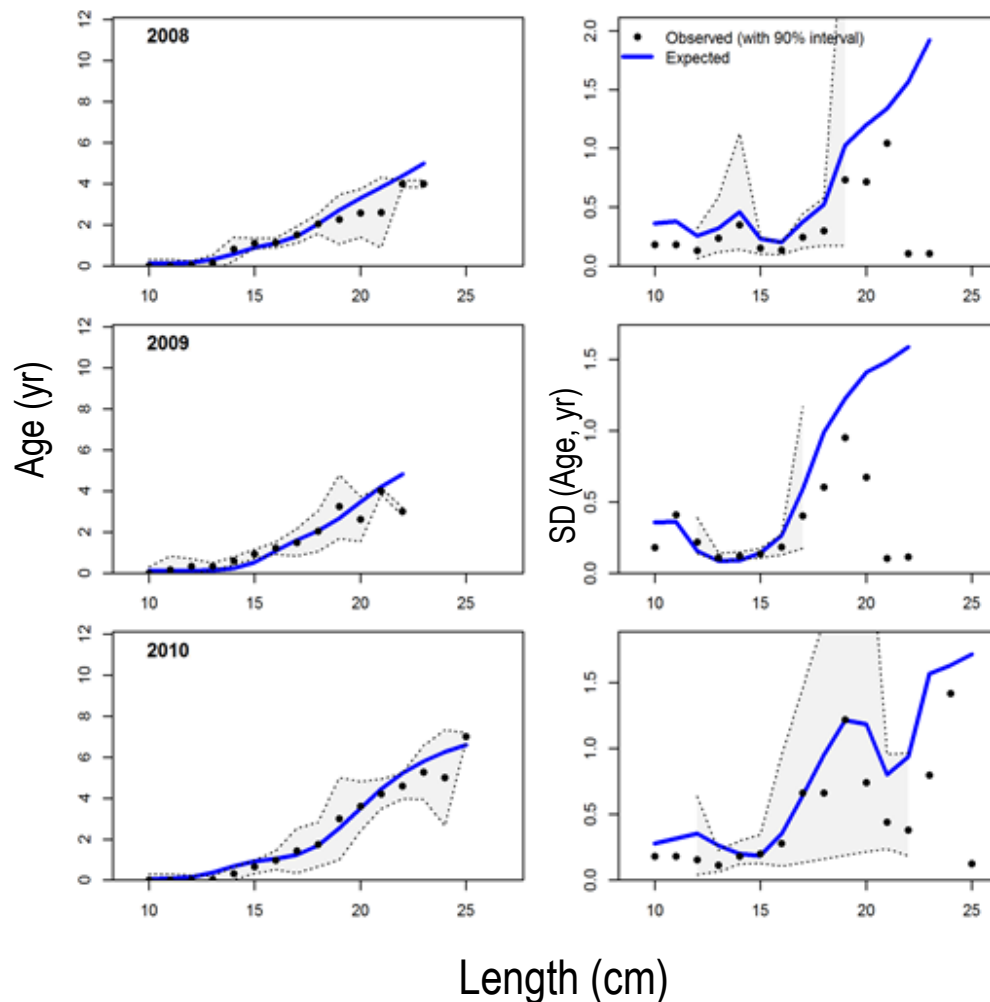
Growth – P. sardine

o Consider bypassing growth estimation
- ✓ Parsimonious model to meet assessment goal
- ✓ Conflicts with modeling selectivity
- ✓ Use mean weight-at-age (empirical)
- ✓ Prerequisite is age-based selectivity

Mean weight-at-age
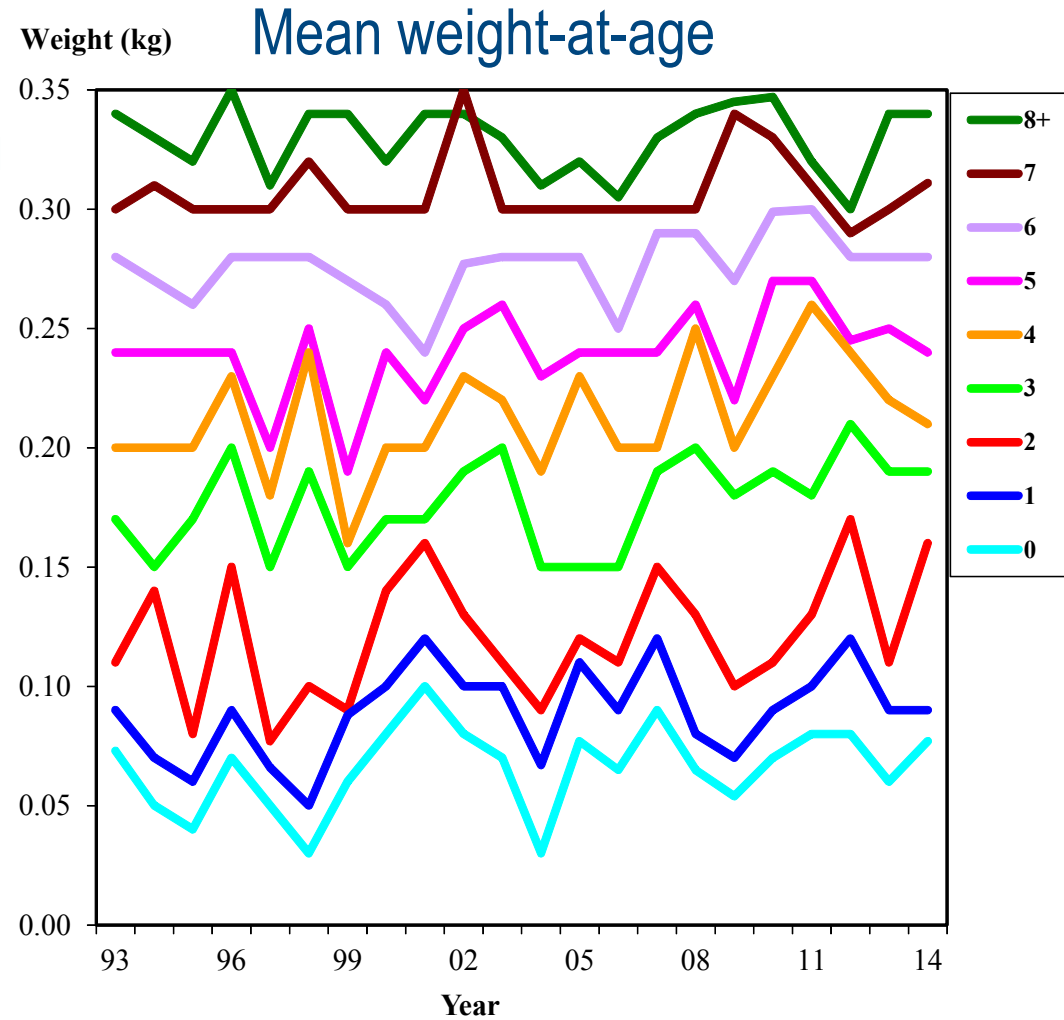
CPS benchmark assessments – Models

- Summary
  - Stock structure
    - ✓ Technical process for delineating northern vs. southern sub-stocks – catch based on regional indices of optimal/good potential habitat better than assuming landing port
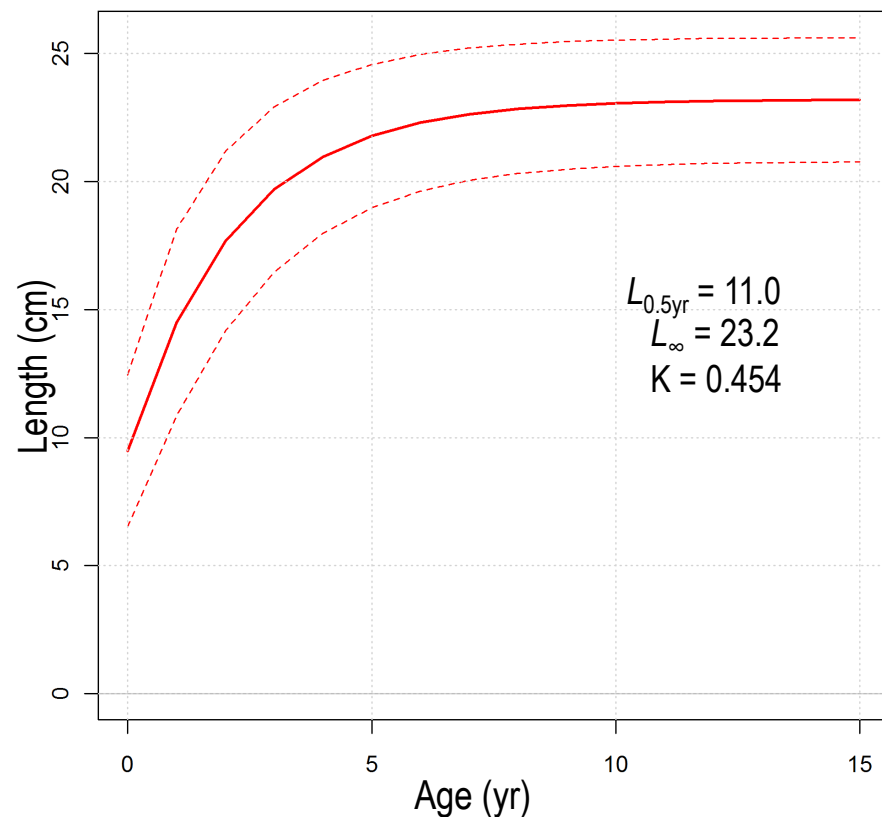   - ✓ Accommodating in management process may be problematic
  - Growth
    - ✓ Revisit use/emphasis of conditional age-at-length data (P. sardine)
    - ✓ Consider fixed/empirical mean weight-at-age
  - Selectivity
    - ✓ Evaluate utility of more straightforward age-based selectivity
  - Spawner-recruit relationship
    - ✓ Recruitment ↔ ecosystem ↔ serial correlation
    - ✓ Adjustments to S-R relation (expected recruitment) based on environmental indices

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CPS research ⟷ Stock assessments

- Field (Acoustic-trawl method survey)
  - Acoustic equipment specifications, estimation, uncertainty (e.g., target strength/backscatter)
  - Optimal sampling design for small pelagic assemblage
  - Inherent timing constraints for acoustic and trawl sampling

- Laboratory (biology)
  - Age/growth/maturity
    - ✓ Otolith microchemistry – empirical evidence supporting environment-based stock delineation hypothesis (P. sardine)
    - ✓ Maturity-at-age/size, fecundity/spawning frequency (P. mackerel)
    - ✓ Marginal increment analysis – examine birth-date/first-year growth assumptions (P. mackerel, P. sardine, N. anchovy)
    - ✓ Age determination consistency for transboundary stocks – SPARC
  - **M. squid**
    - ✓ Refinements to egg escapement model based on laboratory studies
    - ✓ Optimize mantle/gonad preparations for more timely processing
    - ✓ Age/growth of paralarvae, juveniles, adults

- Modeling (critical parameters)
  - **Good practices** – past selectivity workshop/papers and upcoming growth workshop (CAPAM)

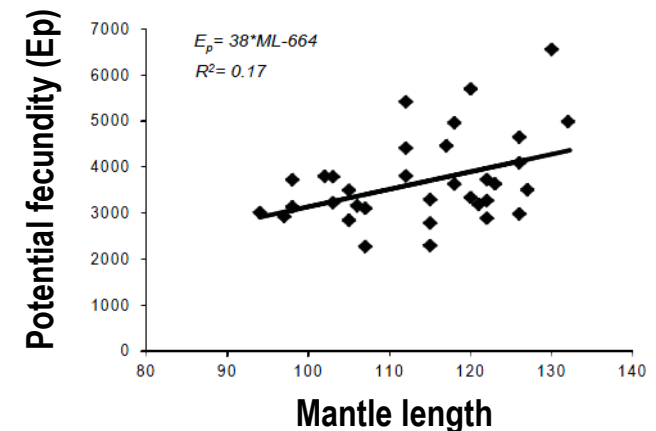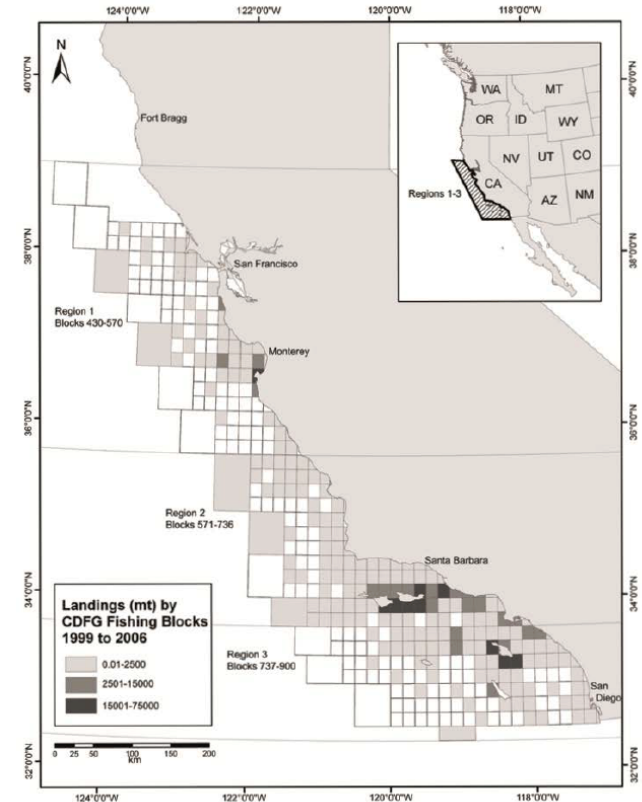# M. Squid – Fishery/management, pop dy/assessment

- Fishery/management/assessment
  - Largest CPS fishery by volume and ex-vessel value
  - Not regularly assessed for setting harvest levels
  - Adaptive management currently, includes weekend closures, seasonal landings cap, and spawning refugia (MPAs)
  - STAR (2001) resulted in development of the egg escapement method (EEM) based on per recruit theory/application (Macewicz et al. 2004, Maxwell et al. 2005; Dorval et al. 2013)

- Life history data for EEM
  - Live approximately 6 months
  - Have determinate (fixed) fecundity
  - Lay egg cases in clutches for approximately 2-3 days, and die after spawning (semelparous)
  - Calculate potential fecundity: standing stock of oocytes of all stages in the ovary of mature pre-ovulatory females
  - Typically harvested on spawning grounds – calculate lost spawning potential due to fishing

Landings (mt) by CDFG Fishing Blocks 1999 to 2006
- 0.01-2500
- 2501-15000
- 15001-75000

$E_p = 38 * ML - 664$
$R^2 = 0.17$

M. Squid research – Egg escapement method (EEM)

EEM application – CA fishery study (Dorval et al. 2013)

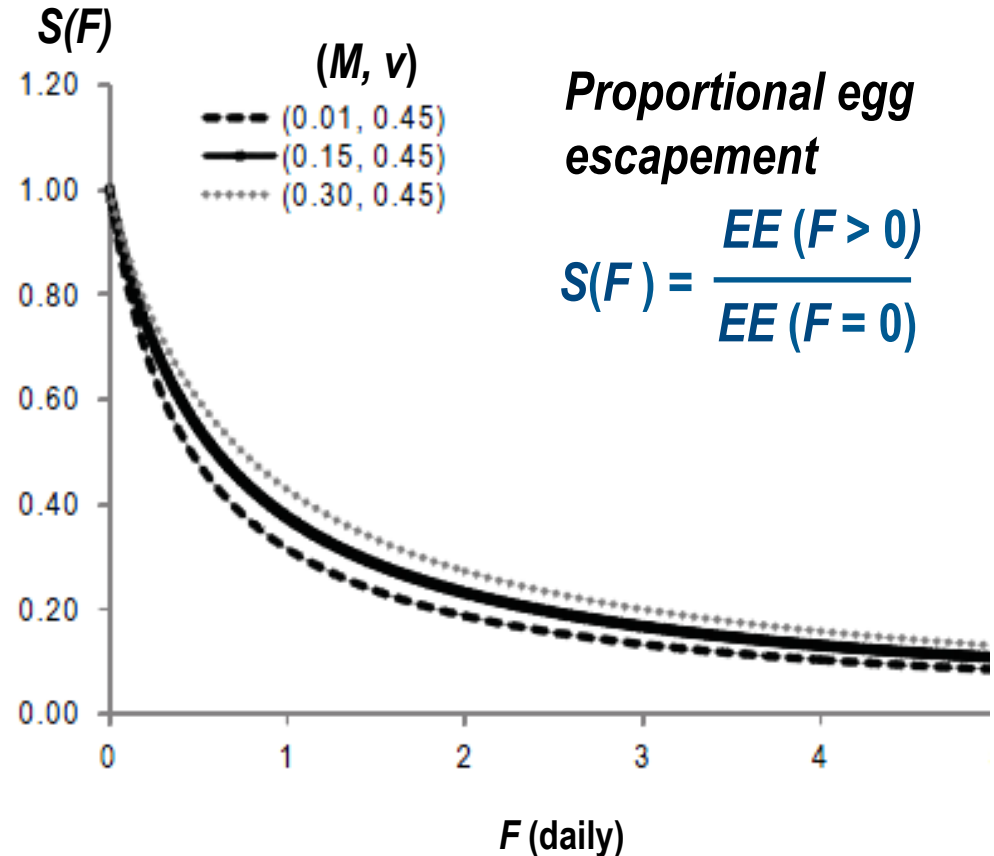- Per recruit conclusions
  - ✓ Although variable within region, proportional egg escapement generally higher than 0.30 in most quarters
  - ✓ Intra-annual variability of recruitment high for some time periods (qtr/yr), but reproductive success generally increased across quarters within region
  - ✓ $S(F)$ similar across regions, i.e., reproductive processes robust to spatial dynamics exhibited in overall fishery
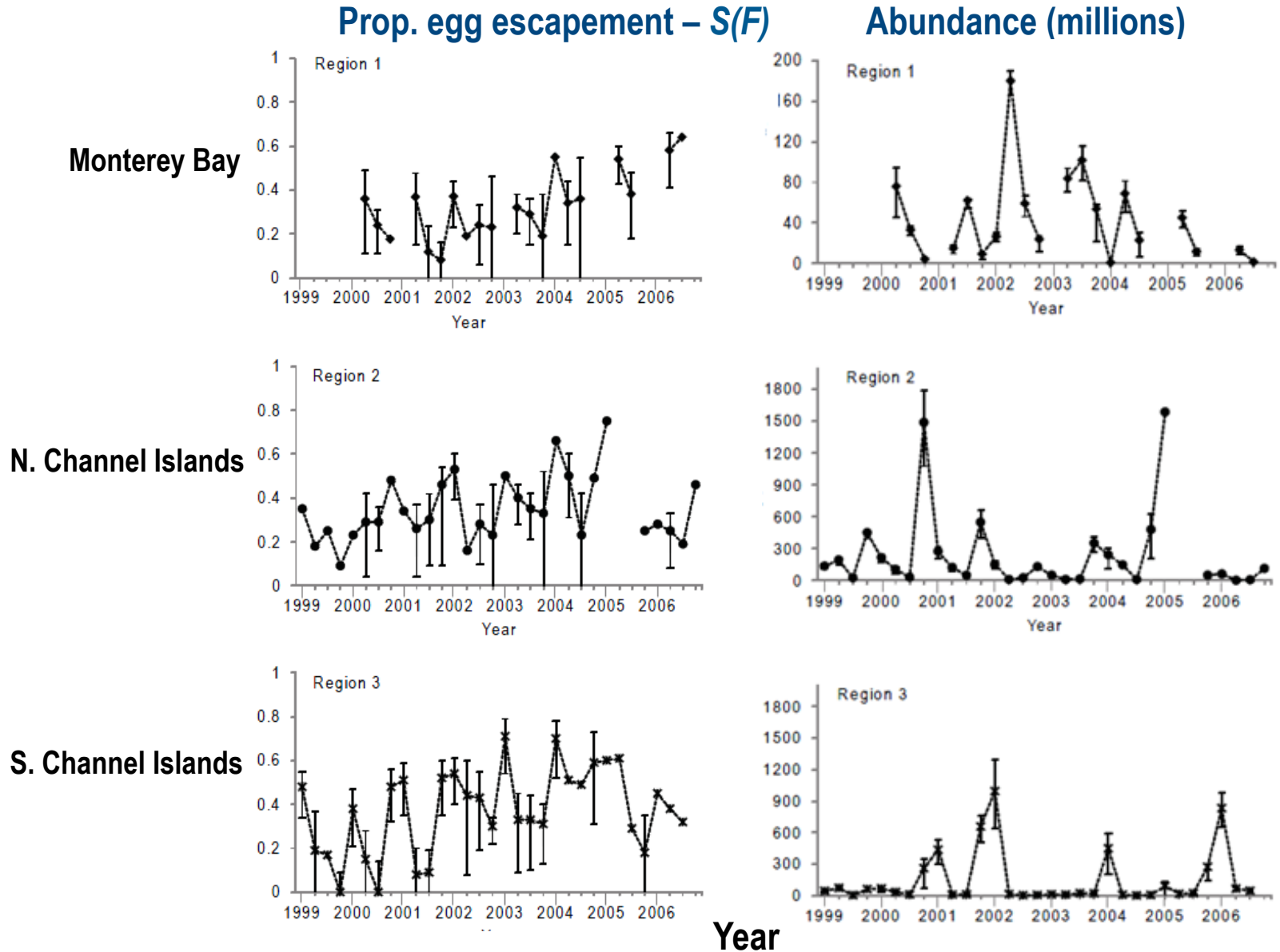- Absolute abundance conclusions
  - ✓ Single population that reproduces disproportionately across extensive spatial range
  - ✓ Absolute abundance derived from fishing mortality inferred from catch fecundity, combined with biological and landing data
  - ✓ Biomass can reach over 250,000 mt in single quarter in regions 2-3, biomass much lower in region 1
- Management implications
  - ✓ Real-time management not practical, given costly/time consuming based on current laboratory processing methods
  - ✓ Consider region-specific harvest stipulations, given spatial differences in abundance
  - ✓ Implementing based on strict threshold level of escapement (e.g., 30%) over long timeframe less efficient than time-varying target levels, given inter-annual variability of $S(F)$
  - ✓ Need to develop longer time series before adopting EEM as formal management tool
  - ✓ Identify environmental indices to inform current more adaptive management efforts

$S(F)$

(M, v)
- - - (0.01, 0.45)
─■─ (0.15, 0.45)
····· (0.30, 0.45)

Proportional egg escapement

$$S(F) = \frac{EE\,(F > 0)}{EE\,(F = 0)}$$

F (daily)

M. Squid research – EEM (CA fishery study)

Prop. egg escapement – *S(F)*   Abundance (millions)

Monterey Bay — Region 1

N. Channel Islands — Region 2

S. Channel Islands — Region 3

Year

Good practices – Modeling selectivity in stock assessments

- Multiple selectivity patterns as a proxy for spatial structure (*fleets as areas* approach) – Hurtado-Ferro, Punt, Hill (2014)
  - Simulated analysis – P. sardine data
  - Design:
    - ✓ Represent spatial structure (areas) with different selectivity curves (fleets)
    - ✓ Evaluate spatial factors for largest effect (migration, composition data, sub-stock assumptions, sampling intensity)
  - Ignoring spatial structure/seasonal migration negatively impacts estimation performance
  - Assessment model compensates for ignoring spatial structure by adjusting selectivity curves
  - Estimated current SSB error influenced by varying migration rates
  - Bottom-line ≡ fleets-as-areas captures some of the variance from spatial structure, but cannot account for all biases
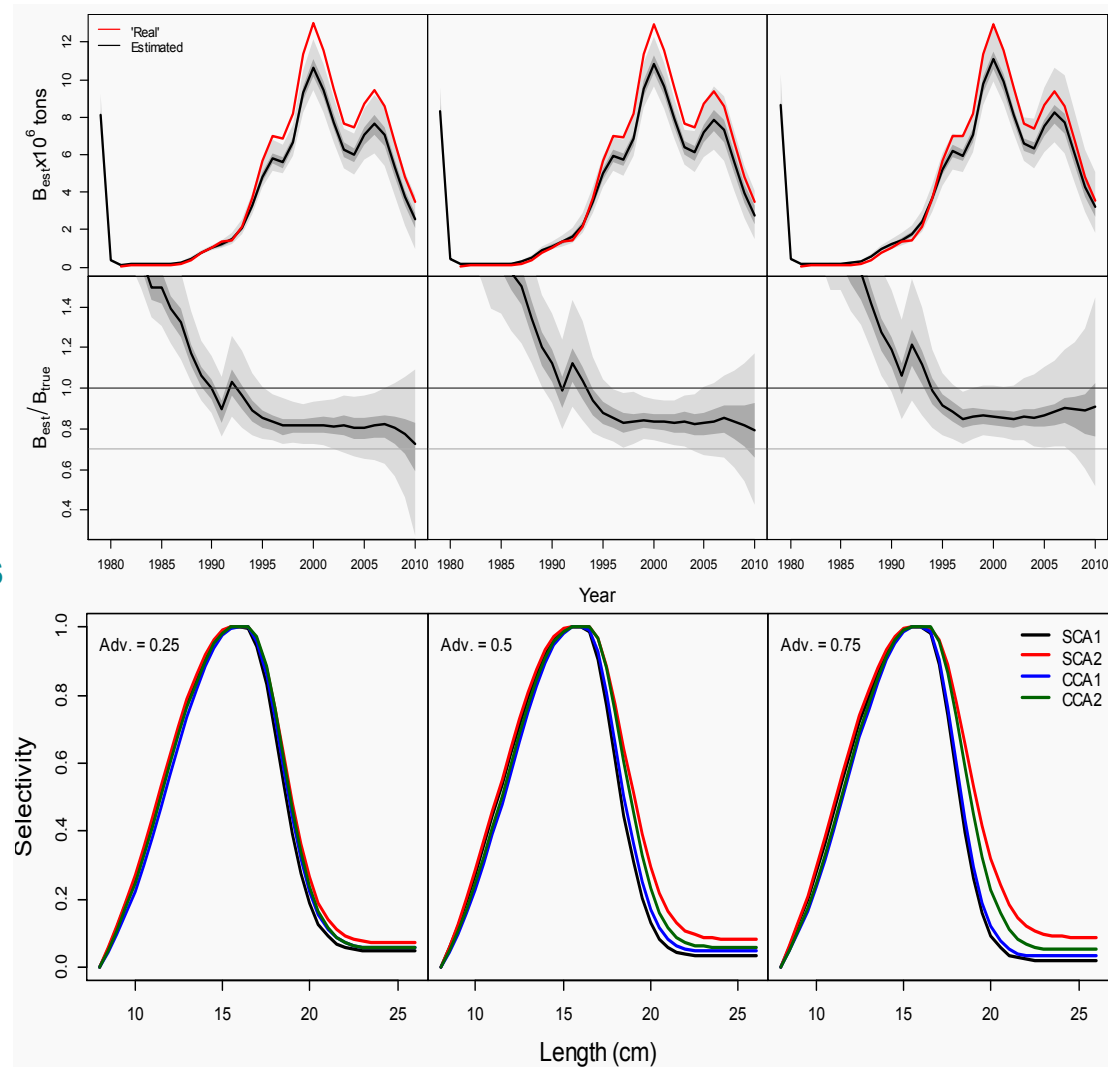
Good practices – Modeling selectivity in stock assessments

- Length vs. age compositions and associated selectivity assumptions – Crone/Valero (2014)

  o Simulated analysis – P. sardine/P. mackerel data

  o Age-composition data more robust to selectivity misspecification than length-composition data

  o When length data are used, misspecification of selectivity generally produced more variable findings and lower quality estimates for *MSY* and $B_{current}$

  o Estimates of depletion more precise/robust
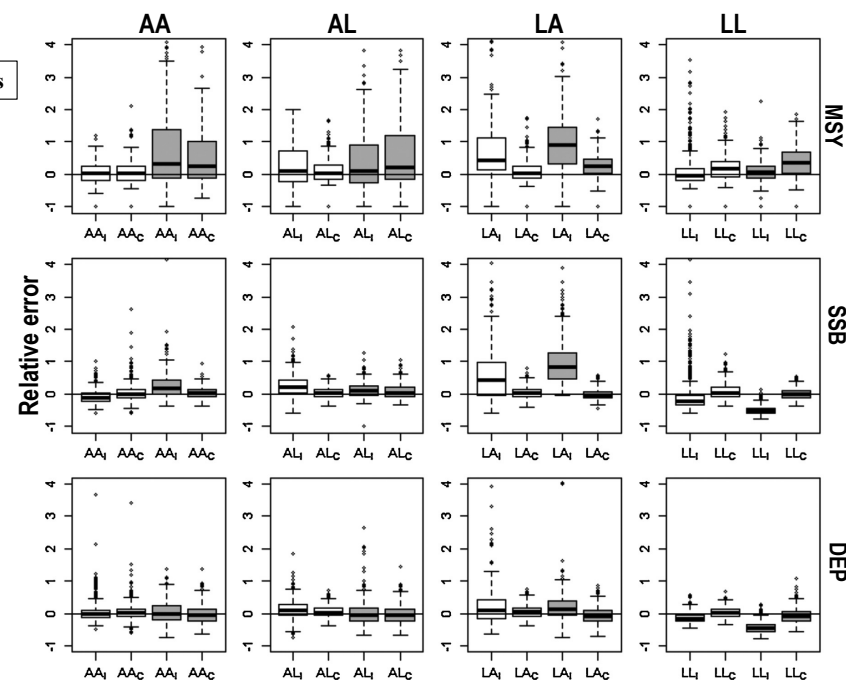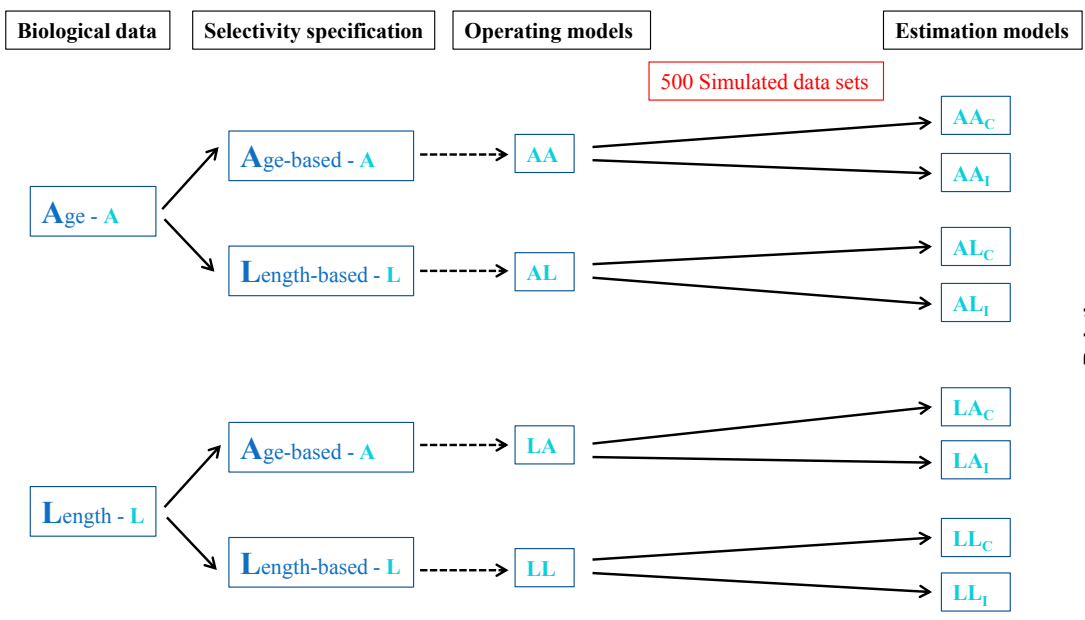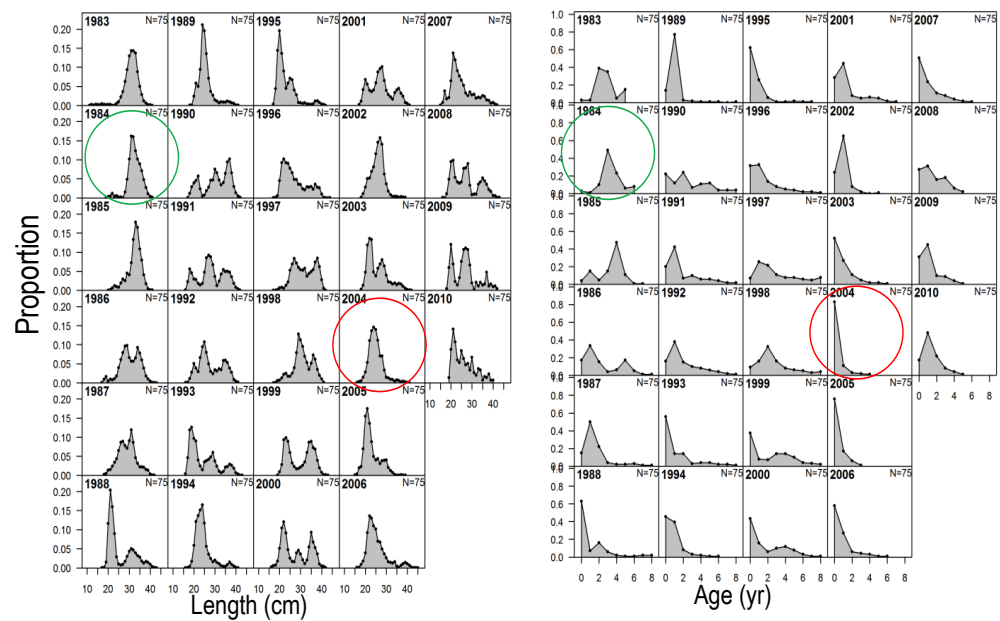
# Good practices – Modeling selectivity in stock assessments

- Selectivity assumptions/data weighting considerations based on likelihood profiling over global scaling parameter – Lee, Piner, Methot, Maunder (2014)
  - Virgin recruitment (R_0) profiles useful for assessing influence of particular data components on population scale
  - Prioritization of data components based on most reliable data and ability to produce internally consistent model on location of population scale
  - Use of additional model process (time varying, more flexible selectivity patterns), and/or composition weighting improved model performance
  - Adding model process preferred to down-weighting in initial misfit investigations
  - Some stock status conclusions may be relatively robust to misspecification e.g., MSY ratio benchmarks (F/F_{MSY}, SSB/SSB_{MSY})

-ln(L)
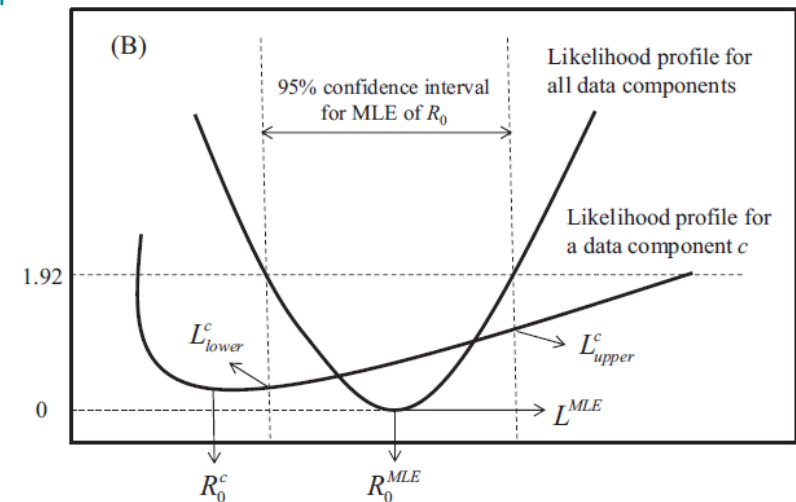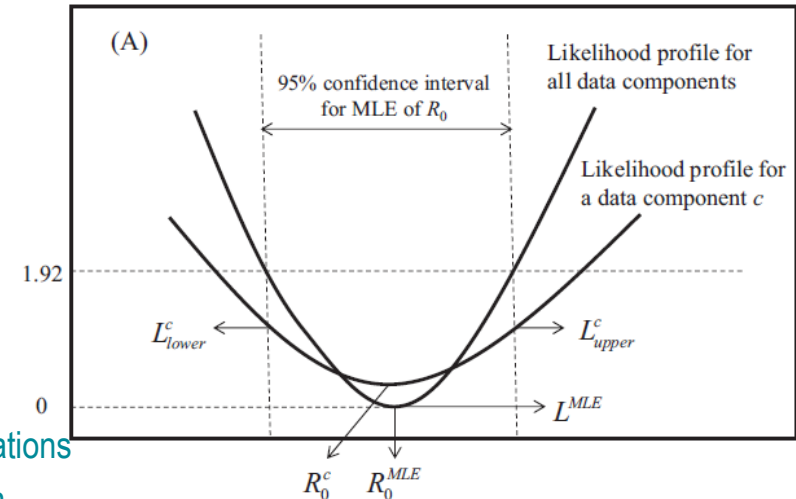
Where we're at ...

CPS landings and abundances
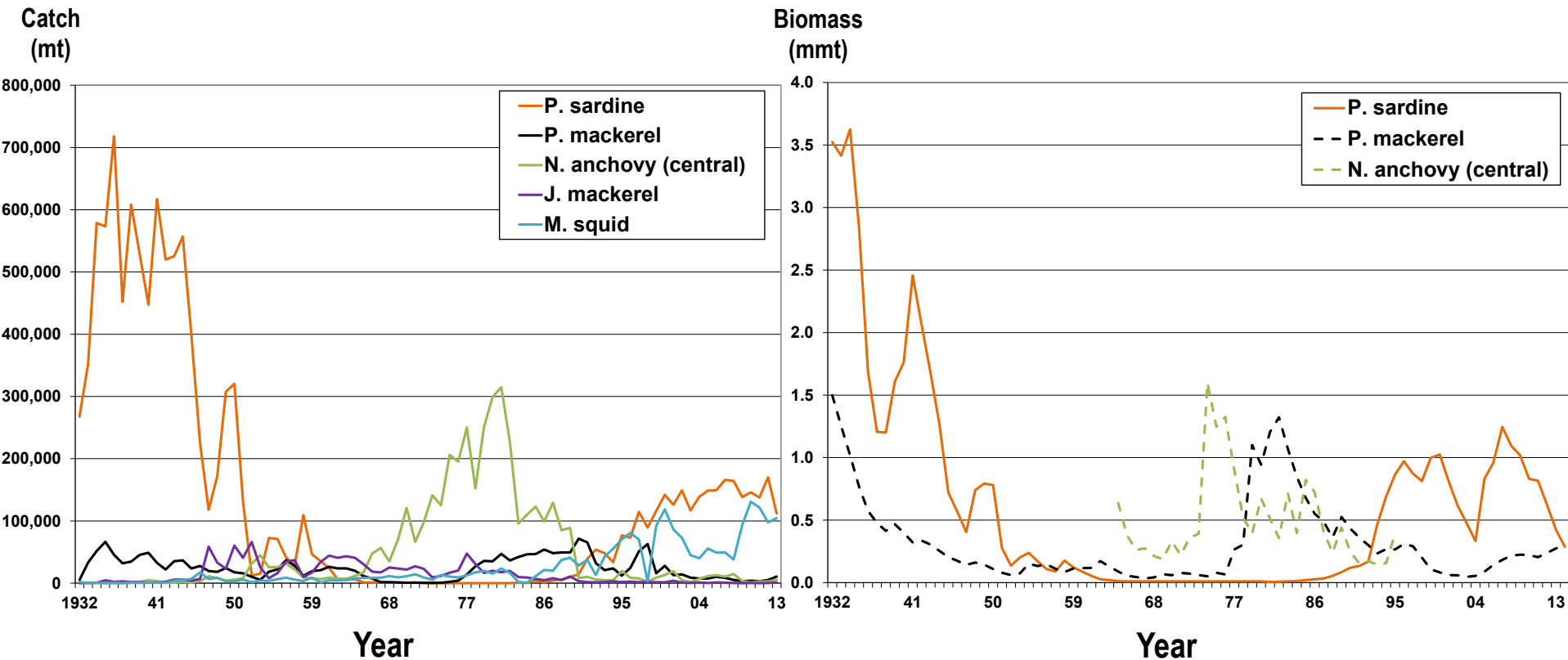
Review theme and questions

- *Theme 1* – Scientific/technical approach for assessing status of CPS fish stocks
  - Is Center using an appropriate suite of analytical methods to meet regional stock assessment objectives?
  - Does the suite of fishery models adequately consider/address/accommodate data-poor to data-rich assessments?
  - Are assessments capable of considering possible ecosystem effects?
  - Does the Center conduct research on analytical methods and assessment model development and contribute to the state-of-the-science nationally and internationally?

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U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service | Page 34

CPS assessments

Strengths

- Data-rich P. sardine assessment continues to improve through ongoing development and peer review

- Acoustic-trawl survey and associated research efforts provide most objective time series of abundance available for assessing status of P. sardine and potentially other CPS

- Laboratory research aids understanding of species' biology

CPS assessments

Challenges

- Foremost, need continues for improved relations with Mexico (less so for Canada) and opportunities to survey (collaboratively or independently) transboundary ranges of CPS

- Sample data/time series necessary for benchmark assessments are incomplete/unavailable for *monitored* CPS stocks

- Identify/incorporate environmental data for informing recruitment estimation in current modeling efforts

- Streamline/standardize CPS assessments to meet management goal

- M. squid monitoring/assessment for advising management on sustainable fishing practices

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CPS assessments

Strategies

- Continue to lobby Mexico administration/technical staff concerning need for collaborative survey efforts

- Continue to support long-term investment in acoustic survey operations (bi-annual, cooperative w/ NWFSC hake survey)

- Design and implement fishery sampling programs for *monitored* CPS

- Develop data-poor assessments for P. mackerel, N. anchovy, J. mackerel (avg. catch, DCAC, DB-SRA, a4a initiative)

- Focused attention via small working groups

  o Alternative methods for modeling environmental time series in Stock Synthesis

  o MSEs – high priority, given ecosystem considerations (merits/drawbacks of data-rich vs. data-moderate models for meeting management goal)

  o Consider management of assemblage vs. species-specific

- Adaptive management along with ecosystem indicators for M. squid